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Towards a Formal Representation of Driving Behaviors

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1 Introduction

To successfully perform their required tasks, agents require accurate and meaningful communication and integration among other agents and information resources. However, the applications and infrastructure of information technology are rife with heterogeneity at many levels. This paper explores applying formal ontologies to address the challenges faced in developing and applying autonomous agents for the purpose of driving unmanned vehicles. Specifically, we are developing a formal ontology to encapsulate the rules of on-road driving, facilitating the ability for an autonomous vehicle to drive on a busy street while following the "rules of the road". This ontology will constitute a major component of the internal knowledge representation within the Real-Time Control System (RCS) [1], which is the architecture that will control the unmanned vehicle.[1]

2 The On-Road Driving Ontology

The ontology focuses upon behaviors for an initial baseline, on-road, autonomous driving capability based on a document capturing driver task descriptions developed for the Department of Transportation (NTIS PB197325) [3]. This document contains a comprehensive inventory of the behaviors involved in operating an automobile, along with the rated criticalities of these behaviors. The task descriptions are organized in terms of the situations that give rise to the behaviors.

For each of the behaviors in the ontology, a vocabulary of task commands and a hierarchy of behavior generation processes are being developed that can accept those

1 This work is being performed under the auspices of the DARPA-funded MARS project [2]. The technology goal of the MARS program is to understand and satisfactorily address the key challenges to the realization of reusable software for autonomous mobile system.

task commands. For a small selected set of behaviors, an in-depth study is being performed of behavior generation processes that decompose the behavior into a sequence of lower level task/behaviors that are expressed in a state-graph formalism at each level of the hierarchy. Specifically, a hierarchy of behavior generating processes is being defined with planning horizons from 50 ms to 100 minutes.

The MARS ontology is represented in the Knowledge Interchange Format (KIF) [4]. An example of a KIF axioms represented in the MARS ontology is included below.

If the force on the car prior to an occurrence of the accelerate activity is ?acc, then the force on the car after the occurrence is increased by the amount ?increment.

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(forall (?car ?acc ?occ ?increment)
        (=>          (and     (occurrence_of ?occ (accelerate ?car ?increment))
                              (prior (force ?car ?acc) ?occ))
                     (holds (force ?car (+ ?acc ?increment)) ?occ)))
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3 Conclusion

The introduction of symbolic data, and more specifically, ontologies, is breaking new ground in the world of autonomous vehicles. There are so many challenges in this field that most researchers are so caught up in the lower levels of the control hierarchy (i.e., not crashing into the static obstacles in front of you), that few, if any, have explored introducing symbolic data. However, the introduction of ontologies has the potential to provide significant value to this field that has up-to-now not been recognized.

Many challenges remain to be addressed, such as the issues related to the integration of symbolic information with lower level map-based and image data. The integration of these two types of information is essential to ensure that all components of the architecture communicate properly, and that all available information is used to make the best decisions possible.

References

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